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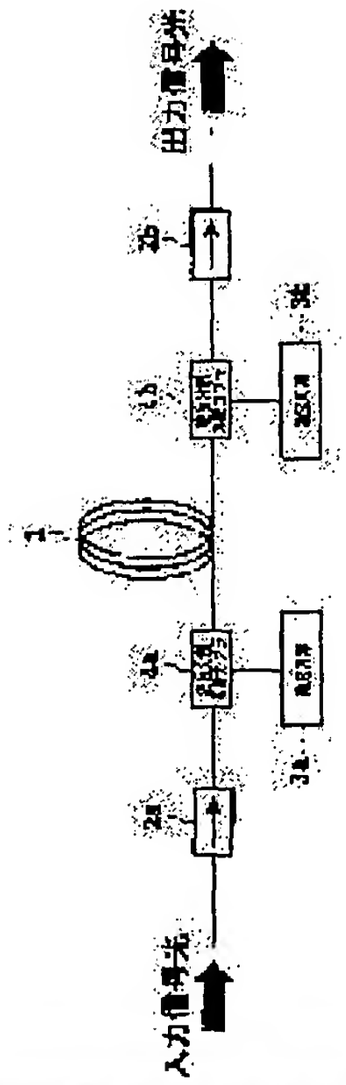
(54) **AMPLIFYING OPTICAL FIBER AND OPTICAL FIBER AMPLIFIER**



(57)Abstract:
PROBLEM TO BE SOLVED: To operate in an amplifying band in a wider range than usual, and amplify effectively.
SOLUTION: A parent phase of a core is composed of a glass oxide containing at least a kind of cation selected from a predetermined element group, and also rare-earth ions are included in at least the core out of the core and a clad to constitute an optical fiber.

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CLAIMS

[Claim(s)]

[Claim 1] The optical fiber for amplification which has a core and clad, and consists of oxide glass with which the host phase of the aforementioned core contained at least a kind of cation chosen from the group which consists of Bi, Pb, K, Cs, Na, Li, Ga, aluminum, In, Zn, Cd, La, Y, Ba, and Sr, and is characterized by the thing of the aforementioned core and the aforementioned clad for which rare earth ion is contained to the core at least.

[Claim 2] The aforementioned rare earth ion is an optical fiber for amplification according to claim 1 characterized by being Tm (thulium).

[Claim 3] The optical fiber for amplification according to claim 1 or 2 characterized by the bird clapper from the oxide glass which contained at least a kind of cation chosen from the group which the host phase of the aforementioned core contains Bi and Ga, in addition becomes from Pb, K, Cs, Na, Li, aluminum, In, Zn, Cd, La, Y, Ba, and Sr.

[Claim 4] It is the optical fiber amplifier with which it is the excitation light source, an optical isolator, a wavelength multi/demulitiplexer, and the optical fiber amplifier constituted using the optical fiber for amplification, and the aforementioned optical fiber for amplification is characterized by the bird clapper from the optical fiber for amplification according to claim 1 to 3.

[Claim 5] Optical fiber amplifier according to claim 4 characterized by having expanded the amplification band to the 1430nm - 1510nm band in the short wavelength region, and expanding it to a 1480nm - 1530nm band in a long wavelength region using the optical fiber for amplification according to claim 1 to 3.

[Claim 6] Optical fiber amplifier according to claim 4 or 5 characterized by having at least one gain equalizer further.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] this invention is used with an optical transmission system etc., and relates to the optical fiber for amplification which has an amplification band in a predetermined wavelength region, and optical fiber amplifier.

[0002]

[Description of the Prior Art] Since it corresponds to large capacity-ization of an optical transmission system accompanying rapid increase of the channel capacity accompanying the spread of the Internet etc., the wavelength multiplex communication system (WDM system) is introduced energetically.

[0003] In this WDM system, it is indispensable to use erbium-doped optical fiber amplifier (EDFA) as a repeater, and the WDM system using the amplification band to 1.53-1.60 micrometers which EDFA has is put in practical use.

[0004] However, in order to correspond to the further large capacity-ization of a communication equipment, it has become important to expand the amplification band of optical fiber amplifier, and development of optical fiber amplifier which covers the low loss field (1.45-1.65 micrometers) of a quartz fiber is desired.

[0005] Thulium (Tm) addition optical fiber amplifier (TDFA) has an amplification band in 1.48-micrometer band, and utilization is expected as optical fiber amplifier which operates by the short wavelength side rather than 1.55-micrometer band amplification region of EDFA.

[0006] Drawing 22 shows the example of the amplification property of TDFA.

[0007] In this drawing 22 , the gain of 20dB or more, the noise figure of 6dB or less, and the good property are realized to 1453-1483nm (30nm of bandwidth) of signal light wave length.

[0008] Drawing 23 shows the energy level of Tm3+.

[0009] inside of drawing 3H4 and 3H5 etc. -- such a high energy state is expressed that the solid line which shows the name of each energy level and shows an energy level is located upwards A ground state N0 is 3H6. It is level and all electrons are in a ground state in the state where incidence of the excitation light is not carried out. 1.4-micrometer band optical amplification by Tm ion 3H4 Level 3F4 An inverted population state is formed between level and it is carried out by causing induced emission changes.

[0010] However, the problem of these changes is upper level. 3H4 It is located level and directly under it. 3H5 Since the energy interval with level is small, it is 3H4. The electrons excited by level are non-radiating changes. 3H5 It is that level HEKUENCHI is

easy to be carried out.
[0011] Here, non-radiating changes show such quick relief that the lattice-vibration energy of the host glass with which Tm ion was added is large. Therefore, it is difficult to realize 1.4-micrometer band optical amplification by the optical fiber for amplification using glass with big lattice-vibration energy, such as quartz glass.
[0012] as the optical fiber for amplification to which the conventional TDFA adds Tm ion in order to solve this problem -- quartz glass -- comparing -- [-- lattice-vibration energy -- small --] -- the influence of non-radiating relief has the feature using the fluoride optical fiber represented by small ZBLAN
[0013] Since changes of 1.4-micrometer band have the life time of fluorescence of lower level (3F4) longer than the life time of fluorescence of the upper level (3H4) of amplification, they have the problem that the inverted population is hard to be formed further again.
[0014] In order to solve this problem, as shown in drawing 23 , once exciting the conventional TDFA from a ground level N0 to the lower level N1 of amplification, the upconversion excitation excited from the lower level of amplification to the upper level N2 of amplification is further used for it.
[0015] By this Upconversion excitation, the ion density of the lower level of amplification is lowered and the improvement of the inverted population is aimed at (31 bibliography : T. Komukai et al. and "Upconversion pumped Thulium-Doped Fluoride Fiber Amplifier and Laser Operating at 1.47micrometer" IEEEJournal of Quantumn Electronics and Vol. No. 11, 1995, and pp. 1880 -1889).
[0016]
[Problem(s) to be Solved by the Invention] However, the long wavelength edge of amplification is located in 1.50 micrometers, and the amplification band of TDFA which uses Tm addition fluoride fiber as the fiber for amplification has the problem in which the field which cannot be amplified to 1.50-1.53 micrometers of fields to 1.53 micrometers which is the short wavelength edge of the amplification band of EDFA remains.
[0017] Drawing 24 shows the absorption spectrum from the ground level (3H6) of Tm3+ of drawing 23 mentioned above to 3H5, and the absorption spectrum from the lower level (3F4) of amplification to 3F2.
[0018] The excitation wavelength of Upconversion excitation is 1000nm - 1120nm, and the absorption to 3F2 from the lower level (3F4) of amplification is exciting it in the large position. Therefore, it is from a ground level (3H6). 3H5 Absorption is small and efficiency is bad.
[0019] Then, by adding the large excitation wavelength of the absorption to the lower level [ground level / (3H6)] (3F4) of amplification the improvement of an excitation efficiency was achieved (T. bibliography: --) Kasamatsu et al. and "Novel 1.50-mum Band Gain-shifted Thulium-Doped Fiber Amplifier by using Dual Wavelength Pumping of 1.05 mum and 1.56 mum" Proc.OAA' 99., PDP1, 1999.
[0020] Furthermore, high interest profit has been obtained by changing the power of the added excitation light in the long wavelength region. TDFA of two-wave excitation had an amplification band in 1480nm - 1510nm, and the bands which cannot be amplified decreased in number slightly.
[0021] However, there is a problem that there is a field which cannot still be amplified to 1510nm - 1530nm.

[0022] Then, the purpose of this invention is to offer the optical fiber for optical amplification which it operates conventionally in a latus amplification band, and can perform efficient amplification, and optical fiber amplifier.
[0023]
[Means for Solving the Problem] this invention has a core and clad, and consists of oxide glass with which the host phase of the aforementioned core contained at least a kind of cation chosen from the group which consists of Bi, Pb, K, Cs, Na, Li, Ga, aluminum, In, Zn, Cd, La, Y, Ba, and Sr, and constitutes the optical fiber for amplification by [of the aforementioned core and the aforementioned clad] containing rare earth ion to a core at least.
[0024] Here, the aforementioned rare earth ion can be set to Tm (thulium).
[0025] The host phase of the aforementioned core may consist of oxide glass which contained at least a kind of cation chosen from the group which contains Bi and Ga, in addition consists of Pb, K, Cs, Na, Li, aluminum, In, Zn, Cd, La, Y, Ba, and Sr.
[0026] This inventions are the excitation light source, an optical isolator, a wavelength multi/demulitiplexer, and optical fiber amplifier constituted using the optical fiber for amplification, and constitute optical fiber amplifier by the aforementioned optical fiber for amplification.
[0027] Here, using the aforementioned optical fiber for amplification, an amplification band may be expanded to a 1430nm - 1510nm band in a short wavelength region, and may be expanded to a 1480nm - 1530nm band in a long wavelength region.
[0028] You may have at least one gain equalizer further.
[0029]
[Embodiments of the Invention] Hereafter, with reference to a drawing, the form of operation of this invention is explained in detail.
[0030] The form of operation of the 1st of the [1st example] this invention is explained based on drawing 1 - drawing 5 .
[0031] (Outline) The outline of this invention is explained first.
[0032] this invention has a core and clad, and consists of oxide glass which contained at least a kind of cation chosen from the group which the host phase of a core becomes from Bi, Pb, Na, Li, K, Cs, Ga, aluminum, In, Zn, Cd, La, Y, Ba, and Sr, and is characterized by the thing of the aforementioned core and the aforementioned clad which rare earth ion contains at least at a core.
[0033] Here, although it is desirable to use the oxide glass which contained at least a kind of cation chosen from the group which consists of Bi, Pb, Na, Li, K, Cs, Ga, aluminum, In, Zn, Cd, La, Y, Ba, and Sr as a host phase of clad, the oxide glass of other type with which the glass transition temperature approached core glass, fluoride glass, etc. can be used.
[0034] moreover, it was chosen out of the group which consists of Pr, Nd, Sm, Eu, Tb, Dy, Ho, Er, Tm, and Yb as rare earth ion contained to a core -- a kind can be used at least Tm (thulium) is used in the rare earth ion.
[0035] (Example) A concrete example is given and explained hereafter.
[0036] The result which examined wholeheartedly the host glass manufactured by the optical fiber for amplification, It is under [oxide glass / which contained at least a kind of cation chosen from the group which consists of Bi, Pb, Na, Li, K, Cs, Ga aluminum, In, Zn Cd, La, Y, Ba and Sr] setting. It found out having a fluorescence spectrum larger than

the time of Tm ion being added in other glass (a tellurite glass, fluoride glass).
[0037] (Refer to drawing 1) Drawing 1 standardizes and shows the fluorescence spectrum obtained when it excited about three kinds of glass which added Tm ion using the white light source with the peak value of fluorescence intensity.
[0038] In drawing 1 , the spectrum A shown as a solid line is acquired from the parent glass of the optical fiber for amplification concerning this invention. Moreover, the spectrum B shown with an alternate long and short dash line is a tellurite glass. The spectrum C shown with a dashed line is fluoride glass.
[0039] This drawing 1 shows that fluorescence-spectrum A of the glass concerning this invention has the latus fluorescence spectrum rather than the spectrums B and C acquired from other glass.
[0040] Therefore, when optical fiber amplifier is constituted using the optical fiber for amplification of this invention, compared with the case where the optical fiber for amplification which consists of other glass is used, it becomes possible to expand the amplification band to a long wavelength region, and it becomes possible to make the amplification band of TDFA approach the amplification band of EDFA.
[0041] (The manufacture method) Next, one example of the production method of the optical fiber for amplification is explained. In addition, this invention is not limited to the following explanation.
[0042] The optical fiber base material by the suction casting method (refer to drawing 2) was produced using the glass of the composition which consists of 60Bi2O3-15Ga2O3-20K2O as clad glass using the glass of the composition which consists of 60Bi2O3-20Ga2O3-20K2O as core glass.
[0043] That is, as shown in drawing 2 (a), anhydrous Bi 2O3, Ga 2O3, and K2 O were prepared, weighing capacity and the mixed batch were put into the golden crucible so that it might become the above-mentioned core and composition of clad, and heating fusion was carried out into oxygen gas atmosphere into the electric furnace. After fusing at 900 degrees C for 1 hour, the temperature was lowered to 700 degrees C and it slushed into the mold 100 currently beforehand heated at 300 degrees C previously from the clad glass melt 101.
[0044] Then, as shown in drawing 2 (b), when solidification of clad glass started and it begins to have cratered the center of the upper part, the core glass melt 102 was slushed.
[0045] Thus, the fiber base material 103 was obtained by core glass's being drawn in a clad glass center section by the volumetric shrinkage accompanying solidification of clad glass, and solidifying by it. Clad outer-diameter 5mmphi and the core outer diameter were changing in the shape of a taper to 0.2-1.7mmphi, and the length of the obtained fiber base material 103 was 30mm.
[0046] Then, the jacketed pipe with the same composition as clad glass was produced by the low TESHONARU casting method.
[0047] That is, after paying the raw material 104 which carried out weighing capacity mixture to the crucible and carrying out heating fusion within an electric furnace so that it may become composition of clad glass, as shown in drawing 3 (a), it slushed into the mold 105 which has heated the raw material 104 beforehand.
[0048] Then, the jacketed pipe 106 with the outer diameter of 15mm, a bore [of 5mm], and a length of 140mm was obtained by carrying out cooling solidification in the state where rotated at high speed while toppling mold 105 horizontally, as shown in drawing 3

(b), and it rotated as it is. One more jacketed pipe 106 was produced by the same method as this.

[0049] Subsequently, as shown in drawing 4 (a), the above-mentioned fiber base material 103 is inserted in a jacketed pipe 106 into the glove box with which the nitrogen gas of -60 degrees C or less of dew-points is supplied, and after holding a jacketed pipe 106 by the vacuum chuck 111 through O ring 110 for base material maintenance, vacuum length of the interior is carried out.

[0050] And as shown in drawing 4 (b), the fiber base material extended by the outer diameter of 5mm is produced by sending at a rate of per minute 3mm in a heating furnace 112, and pulling caudad the lower part of the fiber base material 103 softened by heating.

[0051] Subsequently, among the extended fiber base materials, the core diameter started the portion which is 0.2mm, and considered as the extension base material 113.

[0052] The extension base material 113 was inserted in the jacketed pipe 106 in the interior of the glove box with which the nitrogen gas of -60 degrees C or less of dew-points is supplied after containing the cut-down extension base material 113 and one more jacketed pipe 106 prepared previously in the vacuum heating container 114 and performing dehydration processing by heating as shown in drawing 4 (c), and it set to the drawing furnace upper part, after holding and assembling the upper-limit section by the vacuum chuck 111.

[0053] Thus, a line was drawn on the optical fiber 121 with an outer diameter of 125 micrometers by sending into a drawing furnace at the speed of per minute 3mm, carrying out vacuum length of the interior, and pulling a base material soffit through a roller 120 caudad.

[0054] Thus, the produced optical fiber 121 is the single mode optic fiber deltan=3% and whose core diameter are 2 micrometers, and, as for the loss value of 1.3 micrometers, the thing of 0.2 dB/m and low loss was obtained.

[0055] The [2nd example], next the gestalt of operation of the 2nd of this invention are explained.

[0056] In this example, the single mode optic fiber which uses as core glass glass composition shown in Table 1 (No.1-No.30) by the same manufacture method as the 1st example mentioned above was produced.

[0057]

[Table 1]

No.	Bi_2O_3	PbO	K_2O	Cs_2O	Na_2O	Li_2O	Ga_2O_3	Al_2O_3	In_2O_3	ZnO	CdO	La_2O_3	Y_2O_3	BaO	SrO
1	60		15				25								
2	60		25				15								
3	55	5	15	5			20								
4	55	5	15		5		20								
5	55	5	15			5	20								
6	60		20				15	2.5	2.5						
7	50	5	20				15					2.5	2.5	5	
8	50	5	20				15					2.5	2.5		5
9	50	5	20				15			5		2.5	2.5		
10	50	5	20				15				5	2.5	2.5		
11	65		20				15								
12	65		20				10	5							
13	65		20				10		5						
14	55		15	10			20								
15	55		15		10		20								
16	55		15			10	20								
17	60			20			20								
18	60				20		20								
19	60					20	20								
20	60		20				10	10							
21	60		20				10		10						
22	50	5	20				20				5				
23	50	5	20				20					5			
24	50		20				20						10		
25	50		20				20								10
26	55		20				15			10					
27	55		20				15				10				
28	50	10	20				20								
29	70		20				10								
30	70		15				5	10							

[0058] Thus, when the loss value of the produced single mode fiber was measured by the cutting-back method, the thing of 0.2 - 1.0 dB/m and low loss was obtained for any fiber.
[0059] The [3rd example], next the gestalt of operation of the 3rd of this invention are explained.
[0060] In this example, the single mode optic fiber was produced by the same manufacture method as the 1st example mentioned above, using the tellurite glass of the composition which consists of 60TeO2-20Zn2O-20LiO as clad glass and a jacketed pipe, using the glass of the composition which consists of 60Bi2O3-20Ga2O3-20K2O as core glass.
[0061] When the loss value of the produced single mode fiber was measured by the cutting-back method, the thing of 0.2 - 1.0 dB/m and low loss was obtained for any fiber.
[0062] The [4th example], next the gestalt of operation of the 4th of this invention are explained based on drawing 5 - drawing 7 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0063] (Outline) The outline of this invention is explained first.
[0064] In the optical fiber amplifier equipped with at least one excitation light source, at least one optical isolator, at least one wavelength multi/demulitiplexer, and at least one optical fiber for amplification, it constitutes from this example using the optical fiber for amplification of each example which mentioned above the aforementioned optical fiber for amplification.
[0065] As a wavelength multi/demulitiplexer, a WDM fiber coupler can also be used and a bulked type multi/demulitiplexer may be used.
[0066] Moreover, the composition arranged ahead of the fiber for amplification to the travelling direction of signal light is sufficient as the excitation light source connected to the optical fiber for amplification through a wavelength multi/demulitiplexer, and the composition arranged back is sufficient as it.

[0067] Moreover, you may be the composition arranged at both the front and back. Semiconductor laser may be used as the excitation light source, and solid state laser may be used.
[0068] Furthermore, a fiber laser can also be used as the excitation light source.
[0069] (Example) A concrete example is given and explained hereafter.
[0070] Drawing 5 shows the example of composition of the optical fiber amplifier equipped with the optical fiber for amplification.
[0071] 1 is the optical fiber for amplification explained in the 1st example mentioned above - the 3rd example. The excitation light source in which an optical isolator and 3a generate excitation light in 2a and 2b, and 4a are wavelength division multiplex couplers which multiplex excitation light and 1400nm - 1530nm signal light.
[0072] Drawing 6 shows the gain spectrum 100 of the thulium addition optical fiber amplifier at the time of using the glass concerning this invention as host glass, the gain spectrum 101 of the thulium addition optical fiber amplifier at the time of using fluoride glass as host glass, and the gain spectrum 102 of the thulium addition optical fiber amplifier at the time of using fluoride glass as host glass and using two-wave excitation.
[0073] When optical fiber amplifier is constituted using the optical fiber for amplification of this invention so that this drawing 6 may show, compared with the case where the optical fiber for amplification which consists of fluoride glass is used, and the case where two-wave excitation is used, it becomes possible to expand an amplification band (an amplification band is 1430nm - 1510nm).
[0074] Moreover, drawing 7 shows other examples of an amplification property.
[0075] In this case, the gain spectrum 103 of the thulium addition optical fiber amplifier at the time of using the glass concerning this invention as host glass becomes possible [obtaining high interest profit in a long wavelength region (1480nm - 1530nm)] by making an inverted population state low and extending fiber length.
[0076] The [5th example], next the gestalt of operation of the 5th of this invention are explained based on drawing 8 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0077] Drawing 8 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0078] 1 is the optical fiber for amplification explained in the 1st example mentioned above - the 3rd example. The excitation light source in which an optical isolator and 3a generate excitation light in 2a and 2b, and 4a are wavelength division multiplex couplers which multiplex excitation light and 1400nm - 1530nm signal light.
[0079] Wavelength division multiplex coupler 4a is prepared in the latter part of the optical fiber 1 for amplification.
[0080] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like drawing 6 of the 4th example mentioned above and drawing 7 , and two-wave excitation are used.
[0081] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0082] The [6th example], next the gestalt of operation of the 6th of this invention are explained based on drawing 9 . In addition, about the same portion as each example

mentioned above, the explanation is omitted and the same sign is attached.
[0083] Drawing 9 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0084] 1 is the optical fiber for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a and 2b generate 3a, and 3b generates excitation light, and 4a and 4b are wavelength division multiplex couplers which multiplex excitation light and 1400nm - 1530nm signal light.
[0085] Here, the wavelength division multiplex couplers 4a and 4b are formed before and after the optical fiber 1 for amplification. Moreover, the excitation light sources 3a and 3b are individually formed in the wavelength division multiplex couplers 4a and 4b.
[0086] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0087] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0088] The [7th example], next the gestalt of operation of the 7th of this invention are explained based on drawing 10 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0089] Drawing 10 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0090] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a and 2b generate 3a, and 3b generates excitation light, and 4a and 4b are wavelength division multiplex couplers which multiplex excitation light and 1400nm - 1530nm signal light.
[0091] Here, wavelength division multiplex coupler 4b is arranged among the optical fibers 1a and 1b for amplification.
[0092] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0093] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0094] The gestalt of operation of [the example of the octavus], next the octavus of this invention is explained based on drawing 11 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0095] Drawing 11 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0096] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a and 2b generate 3a, and 3b generates excitation light, and 4a and 4b are wavelength division multiplex couplers which multiplex excitation light and 1400nm - 1530nm signal light.
[0097] Here, wavelength division multiplex coupler 4a is arranged among the optical fibers 1a and 1b for amplification.

[0098] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0099] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0100] The [9th example], next the gestalt of operation of the 9th of this invention are explained based on drawing 12 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0101] Drawing 12 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0102] 1 is the optical fiber for amplification explained in the 1st example mentioned above - the 3rd example. The excitation light source in which an optical isolator and 3a generate excitation light in 2a and 2b, and 4a are wavelength division multiplex couplers which multiplex excitation light and 1400nm - 1530nm signal light, and 5 is a gain equalizer further.
[0103] Here, the gain equalizer 5 is formed in the output stage. Only one wavelength division multiplex coupler 4a is prepared in the preceding paragraph of the optical fiber 1 for amplification.
[0104] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0105] Furthermore, it becomes possible by forming the gain equalizer 5 to make a gain spectrum flat over a wide band.
[0106] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0107] In addition, although it has the work which crosses amplification gain to an amplification band and makes it flat as WDM system application, when there is no need of making it flat, it is not necessary to use the gain equalizer 5.
[0108] The [10th example], next the gestalt of operation of the 10th of this invention are explained based on drawing 13 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0109] Drawing 13 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0110] 1 is the optical fiber for amplification explained in the 1st example mentioned above - the 3rd example. The excitation light source in which an optical isolator and 3a generate excitation light in 2a and 2b, the wavelength division multiplex coupler with which 4a multiplexs excitation light and 1400nm - 1530nm signal light, and 5 are gain equalizers.
[0111] Here, the optical fiber 1 for amplification is formed between optical-isolator 2a and wavelength division multiplex coupler 4a.
[0112] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.

[0113] Furthermore, it becomes possible by using the gain equalizer 5 to make a gain spectrum flat over a wide band.
[0114] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0115] The [11th example], next the gestalt of operation of the 11th of this invention are explained based on drawing 14 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0116] Drawing 14 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0117] 1 is the optical fiber for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a and 2b generate 3a, and 3b generates excitation light, the wavelength division multiplex coupler with which 4a and 4b multiplex excitation light and 1400nm - 1530nm signal light, and 5 are gain equalizers.
[0118] An output stage is made to add the gain equalizer 5 to the composition of the 6th example (refer to drawing 9) mentioned above here.
[0119] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0120] Furthermore, it becomes possible by using the gain equalizer 5 to make a gain spectrum flat over a wide band.
[0121] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0122] The [12th example], next the gestalt of operation of the 12th of this invention are explained based on drawing 15 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0123] Drawing 15 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0124] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a and 2b generate 3a, and 3b generates excitation light, the wavelength division multiplex coupler with which 4a and 4b multiplex excitation light and 1400nm - 1530nm signal light, and 5 are gain equalizers.
[0125] An output stage is made to add the gain equalizer 5 to the composition of the 7th example (refer to drawing 10) mentioned above here.
[0126] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0127] Furthermore, it becomes possible by using the gain equalizer 5 to make a gain spectrum flat over a wide band.
[0128] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0129] The [13th example], next the gestalt of operation of the 13th of this invention are explained based on drawing 16 . In addition, about the same portion as each example

mentioned above, the explanation is omitted and the same sign is attached.
[0130] Drawing 16 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0131] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a and 2b generate 3a, and 3b generates excitation light, the wavelength division multiplex coupler with which 4a and 4b multiplex excitation light and 1400nm - 1530nm signal light, and 5 are gain equalizers.
[0132] An output stage is made to add the gain equalizer 5 to the composition of the example (refer to drawing 11) of the octavus mentioned above here.
[0133] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0134] Furthermore, it becomes possible by using the gain equalizer 5 to make a gain spectrum flat over a wide band.
[0135] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0136] The [14th example], next the gestalt of operation of the 14th of this invention are explained based on drawing 17 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0137] Drawing 17 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0138] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a and 2b generate 3a, and 3b generates excitation light, the wavelength division multiplex coupler with which 4a and 4b multiplex excitation light and 1400nm - 1530nm signal light, and 5 are gain equalizers.
[0139] Here, in addition to the composition of the 7th example (refer to drawing 10) mentioned above, the gain equalizer 5 is formed between optical fiber 1a for amplification, and wavelength division multiplex coupler 4b.
[0140] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0141] Furthermore, it becomes possible by using the gain equalizer 5 to make a gain spectrum flat over a wide band.
[0142] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0143] The [15th example], next the gestalt of operation of the 15th of this invention are explained based on drawing 18 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0144] Drawing 18 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0145] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in

which 2a and 2b generate 3a, and 3b generates excitation light, the wavelength division multiplex coupler with which 4a and 4b multiplex excitation light and 1400nm - 1530nm signal light, and 5 are gain equalizers.
[0146] Here, in addition to the composition of the example (refer to drawing 11) of the octavus mentioned above, the gain equalizer 5 is formed between wavelength division multiplex coupler 4a and optical fiber 1b for amplification.
[0147] The gain spectrum of this example becomes possible [expanding the amplification band to a long wavelength region] compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0148] Furthermore, it becomes possible by using the gain equalizer 5 to make a gain spectrum flat over a wide band.
[0149] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0150] The [16th example], next the gestalt of operation of the 16th of this invention are explained based on drawing 19 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0151] Drawing 19 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0152] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a, 2b, and 2c generate 3a, and 3b generates excitation light, the wavelength division multiplex coupler with which 4a and 4b multiplex excitation light and 1400nm - 1530nm signal light, and 5 are gain equalizers.
[0153] Here, in addition to the composition of the 14th example (refer to drawing 17) mentioned above, optical-isolator 2b is prepared between optical fiber 1a for amplification, and the gain equalizer 5.
[0154] The gain spectrum of this example becomes possible [making a gain spectrum flat over a wide band] by expanding the amplification band to a long wavelength region, and using a gain equalizer compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0155] Furthermore, it becomes possible by inserting an optical isolator between two optical fibers for amplification to remove the return light from optical fiber 1for amplification b.
[0156] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0157] The [17th example], next the gestalt of operation of the 17th of this invention are explained based on drawing 20 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0158] Drawing 20 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0159] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a, 2b, and 2c generate 3a, and 3b generates excitation light, the wavelength division multiplex coupler with which 4a and 4b multiplex excitation light and 1400nm -

1530nm signal light, and 5 are gain equalizers.
[0160] Here, in addition to the composition of the 15th example (refer to drawing 18) mentioned above, optical-isolator 2b is prepared between wavelength division multiplex coupler 4a and the gain equalizer 5.
[0161] The gain spectrum of this example becomes possible [making a gain spectrum flat over a wide band] by expanding the amplification band to a long wavelength region, and using the gain equalizer 5 compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0162] Furthermore, it becomes possible by inserting optical-isolator 2b between two optical fibers 1a and 1b for amplification to remove the return light from optical fiber 1for amplification b.
[0163] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0164] The [18th example], next the gestalt of operation of the 18th of this invention are explained based on drawing 21 . In addition, about the same portion as each example mentioned above, the explanation is omitted and the same sign is attached.
[0165] Drawing 21 shows the example of composition of the optical fiber amplifier using the optical fiber for amplification concerning this invention.
[0166] 1a and 1b are the optical fibers for amplification explained in the 1st example mentioned above - the 3rd example. An optical isolator, the excitation light source in which 2a, 2b, and 2c generate 3a, and 3b generates excitation light, the wavelength division multiplex coupler with which 4a and 4b multiplex excitation light and 1400nm - 1530nm signal light, and 5 are gain equalizers.
[0167] Here, deformation is added to the composition of the 17th example (refer to drawing 20) mentioned above, and optical fiber 1a for amplification is arranged between wavelength division multiplex coupler 4a and optical-isolator 2b.
[0168] The gain spectrum of this example becomes possible [making a gain spectrum flat over a wide band] by expanding the amplification band to a long wavelength region, and using the gain equalizer 5 compared with the case where the case where the optical fiber for amplification which consists of fluoride glass is used like the 4th example mentioned above, and two-wave excitation are used.
[0169] Furthermore, it becomes possible by inserting optical-isolator 2b between two optical fibers 1a and 1b for amplification to remove the return light from optical fiber 1for amplification b.
[0170] Moreover, it becomes possible by worsening an inverted population state and extending fiber length to obtain high interest profit in a long wavelength region.
[0171]
[Effect of the Invention] As explained above, according to this invention, it consists of oxide glass which contained at least a kind of cation chosen from the predetermined element group in the host phase of a core. And since inside [it is a core and clad] made the core contain rare earth ion at least and the optical fiber was constituted While being able to expand the amplification bandwidth to a short wavelength region and a long wavelength region and being able to offer the high light amplifier of efficiency by this in 1.48-micrometer band close to the amplification band of EDFA It becomes possible to make the number of wavelength of a WDM system increase, and to large-capacity-ize,

and if it lengthens, low-cost-izing and highly-efficient-izing of an optical transmission system can be attained.

[Translation done.]